

Evaluation system for brain function using MEG, internet, and high performance computing

Y. Mizuno-Matsumoto^{1,2,3}, S. Date², Y. Kadobayashi², S. Shimojo², H. Tatsumi⁴,
K. Shinosaki², M. Takeda², T. Inouye⁵, S. Tamura², and H. Miyahara²

¹Johns Hopkins University, Baltimore, USA; ²Osaka University, Osaka, Japan;

³Osaka Jonan Women's College, Osaka, Japan; ⁴Sapporo Medical College, Sapporo, Japan;

⁵Osaka Prefectural College of Health Sciences, Osaka, Japan

1 Introduction

MEG (Magnetoencephalography) is being investigated in the hope that will provide accurate localization of cerebral current sources and propagation of brain information. However, the brain is complex in comparison with other organs, which means that high-technology equipment, staff possessing specialized medical knowledge, large volume of data and much time to process them are required to adequately investigate and evaluate brain function in detail. Moreover, not only are these high-technology medical devices themselves extremely expensive, their running costs are also high. One important way to reduce costs without lowering the quality of medical services is to increase efficiency. We propose a new system of brain function evaluation that combines MEG, internet and high performance computers.

2 Methods

2.1 System overview

MEG has chiefly been used for research rather than for routine clinical evaluation of brain function because: 1) the cost is very high; 2) the number of instruments available is limited; and 3) measurement, analysis and diagnosis require the use of advanced techniques. In the current MEG system, the multichannel data stream from the MEG modality is recorded and stored on a disk device such as a magneto-optical disk, brought back to the laboratory, and analyzed using a single computer. Logistical problem with this setup means that data cannot easily be collected, analyzed, and visualized in sequential operations. The inefficiency of the procedures is another important reason why MEG is not often employed. In addition, we have developed a new algorithm, wavelet-crosscorrelation analysis, to reveal brain function from MEG data [1][2]. However, it takes tremendous time to calculate data using such a

high-quality analysis by usual sequential method on a single computer.

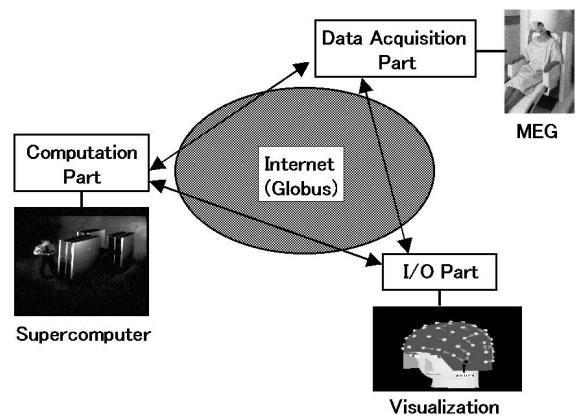


Figure 1. Integration of MEG data, signal processing and visualization system for diagnosis.

We have reported the preliminary study of the integrated system [3] in addition to high-quality analysis, named wavelet-crosscorrelation analysis, of brain function [2]. We propose an integrated system (Fig. 1) for the evaluation of brain function. In this system individual specialists work on measurement, analysis and diagnosis, respectively, and the data including raw data and the analyzed results are transferred from one node to another via a network. In other words, the system consists of three main components: (1) a data collection component (MEG); (2) an analysis component; and (3) a visualization component (diagnosis). In the data collection component, a large volume data is received from MEG modality. In the analysis component, parallel computing is performed using wavelet-crosscorrelation analysis. Also, the visualization component depicts the results of the brain function analysis to facilitate diagnosis and decision making. Their components are connected via a network, called Globus system [4], which has the ability to exploit various sources that are geographically distributed. Moreover, in an analysis

part, MPI (message communication library), with which efficient parallel processing can be performed, is used.

2.2 Metacomputing

We propose utilizing the Globus system, which has the ability to exploit various sources that are geographically distributed [4][5]. The Globus project is a multi-institutional research effort that seeks to enable the construction of computational grids providing pervasive, dependable and consistent access to high-performance computational resources and users. Metacomputers are networked virtual supercomputers. The Globus system, through which metacomputers are constructed, is intended to achieve a vertically integrated treatment of application, middleware and network. The Globus system thus provides the possibility of constructing high-performance applications on a high-speed network. With the geographical problems solved, real-time processing from data collection via analysis to visualization can be realized.

2.3 Parallel computing

We propose utilizing parallel computing on a message-passing interface (MPI) [6] in each supercomputer. Message passing is a paradigm used widely on certain classes of parallel machines, especially those with distributed memory. In other words, MPI is the message communication library with which efficient parallel processing can be performed.

In this research we divided the process to calculate MEG data into multiple processes. We can analyze MEG data faster using the parallel computing than using the ordinal sequential computing.

2.4 Implementation

In the data collection component, the MEG data stream is directly input into a computer connected the Globus system (Fig. 1).

In the next step, parallel computing is performed. However, considerable time is needed to complete the analysis by usual sequential method on a single computer.

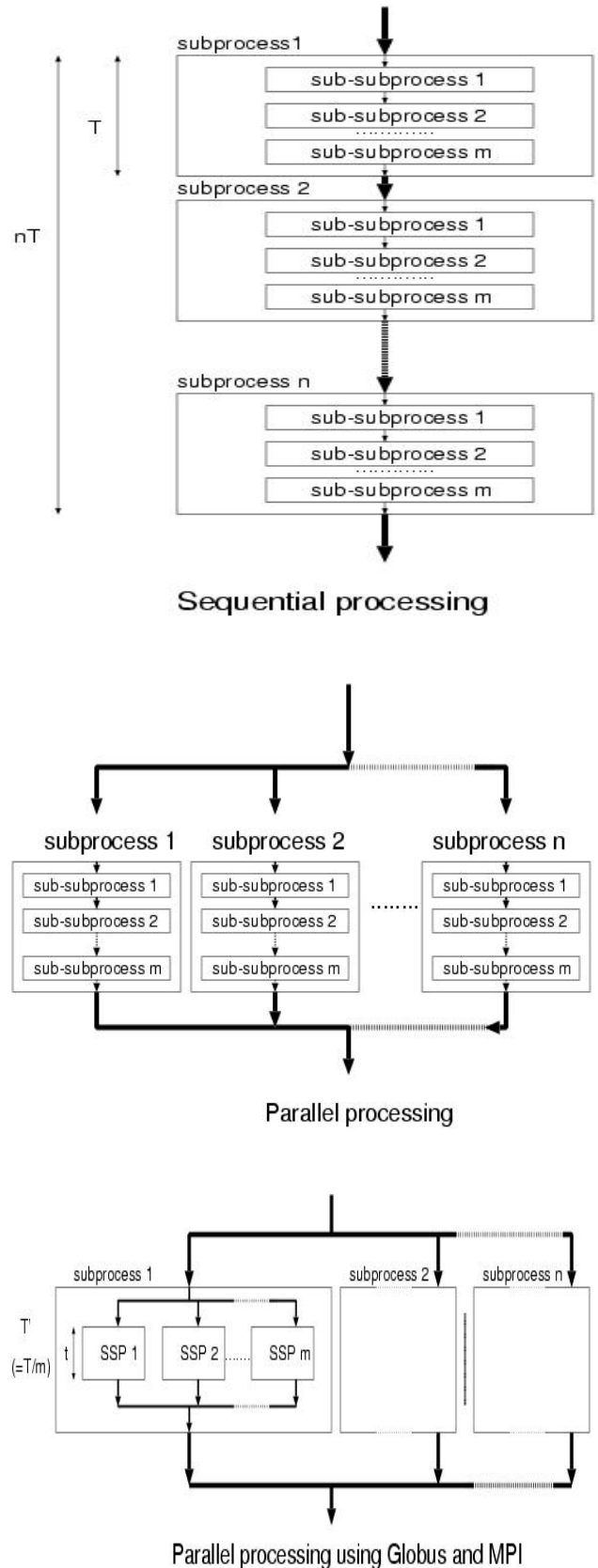


Figure 2. Sequential processing and parallel processing.

Figure 2 shows schematically the difference between the sequential processing and parallel processing. Using a sequential system, nT seconds are required to process data, where n is the number of supercomputers and T is the processing time of each data set. The second diagram shows the parallel processing using Globus. Using Globus system, only T seconds are needed to calculate all the data sets when the task is divided into n processes. The sub-processes are themselves then further divided into multiple sub-processes using MPI. In this way, the process time can be reduced from mt to t seconds, where m is the number of CPUs and t is the processing time of each sub-sub-process. Totally, data will be processed in $T' = T/m$ seconds using Globus combined with MPI.

Figure 3-1 and 3-2 show the visualization software which has been designed includes not only a sophisticated viewer but also a communications element. In other words, interactive visualization is performed under remote control, enabling a medical doctor, who can be located far from the instrument and the computers used for analysis, to diagnose a brain disorder. Figure 3-1 depicts the raw data viewer. Figure 3-2 depicts the snap shot of three-dimensional mapping movie of the analyzed results. Using wavelet-crosscorrelation analysis, the appearing sites of the waves (e.g. epileptiform discharges) and information on propagation can be shown in the map.

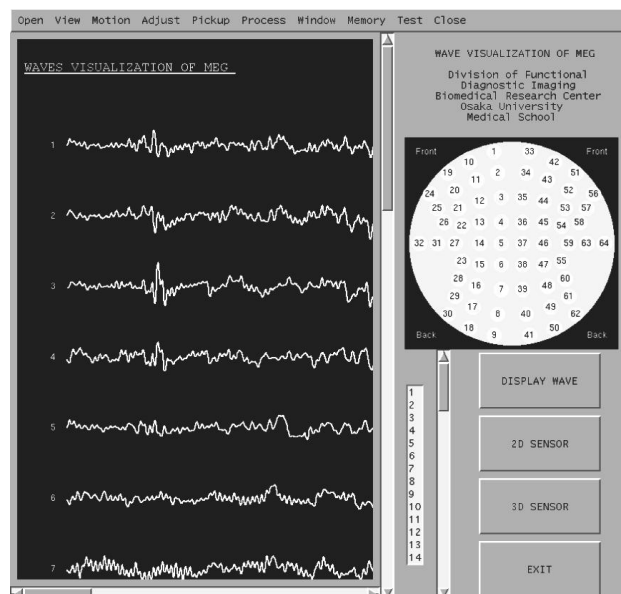


Figure 3-1. User interface: raw data viewer.

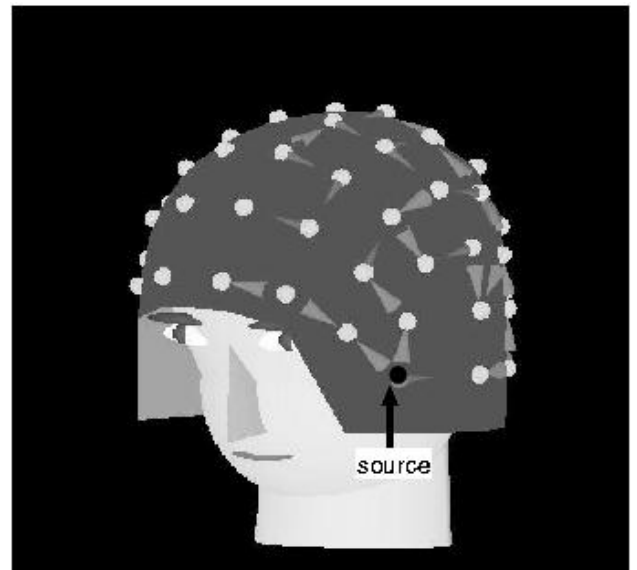


Figure 3-2. User interface: three-dimensional viewer.

3 Results

Simulations were performed to evaluate the performance of the parallel computing system. Two nodes (supercomputers) and a total of 16 CPUs were employed. Performance times were determined using various numbers of processors (1-16) and different data lengths (200-2000 pieces of data). The trial under each condition was performed 30 times. Figure 4 shows the averaged performance times. It takes 22 times faster to assess the brain function in the proposed system with 16 CPUs than in the conventional system with 1 CPU.

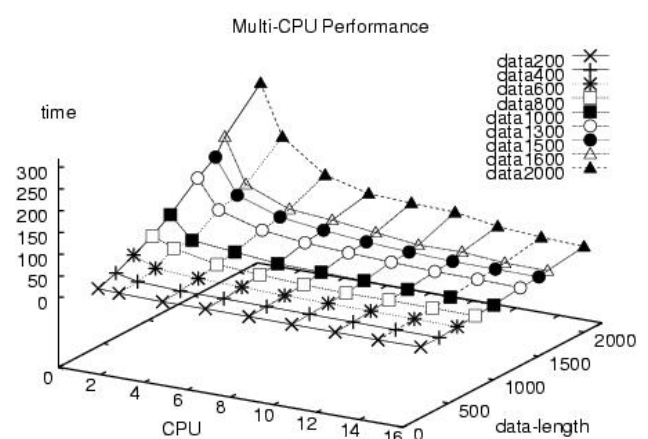


Figure 4. Performance time.

4 Discussion

Telemedicine has the potential to contribute to provision of high-quality and low-cost health care. One advantage of using the Globus system in medical fields is that it allows different types of computers and different kinds of hardware to be connected together. Increasing efficiency to assess the brain function would make it possible to diagnose the brain damage promptly and to detect the disorders in the early stage.

The simulation indicates that computational grid has the potential to bring us enormous calculation power and to integrate geographically distributed resources. The solution for geographical distribution problems may lead us to the possibilities to remote diagnosis in many kinds of medical fields in the future.

Acknowledgements

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